Transport 9

9.1 Trucks

The productivity of truck transport is affected by the load size and the number of round trips (turns) made per day. To be effective, the truck should have a short terminal time (time for loading and unloading) and a reasonably high traveling speed. In most cases, truck transport starts from a landing. However, when the terrain is gentle and the soil strong enough, truck transport can be started from the stump site.

Transport distances may vary from some kilometers up to hundreds of kilometers. A product of low value, such as fuel wood, can be transported economically only over relatively short distances. Valuable roundwood, however, can be transported over much longer distances. In some countries, a suitable transport distance for two round trips per day is about 80 km. With poor road conditions only one round trip per day may be possible over such a distance.

9.1.1 Equipment

The choice of a suitable truck depends mainly on the size and form of the wood transported, transport distance, load-bearing capacity of roads and bridges, as well as conditions of loading and unloading. The choice of truck is also affected by possibilities for proper service and the availability of spare parts.

For timber transport, the trucks can be equipped with a flat bed, or steel body, and timber bunks with load-supporting stakes (stanchions) and binders for the load. Sometimes they are also equipped with a loading device. When choosing suitable truck units (rigs) for different transport conditions, selection must be made between the following alternatives:

- Two, three, or more axles
- Single, dual, or bogie wheels
- One, two, three, or more driving axles
- Load space on the driving unit or separate one-axle wheel attachment, separate bogie, semitrailer, or full trailer

When choosing a truck with a suitable load space, the common lengths and weights of the wood species to be transported have to be known. After that, the bearing capacity of the roads and bridges affect the choice. Restrictions on total allowable weights and the minimum allowable distance between the outer axles as well as the minimum allowable axle weight and the total length of the truck unit vary from country to country. Some types of timber trucks and their typical load capacities are presented (Fig. 9.1), where the first number expresses the number of wheels (or dual wheels), and the second number is the number of driving wheels (powered wheels):

- A single two-axle truck, also called a straight truck or four-wheel truck (configuration 4×2 or 4×4; load capacity 8–12 m^3).
- A single three-axle truck with double or bogie wheels at the rear end (6×4 or 6×6; 10–15 m^3).
- A two-axle truck, also called a truck-tractor, with a separate wheel attachment which is fastened to the log load (truck usually 4×2, with wheel attachment 20–25 m^3).
- A three-axle truck with a double-axle semitrailer, which may be equipped with a flat bed for shortwood or with a steel body and timber bunks with stakes for longwood (usually 6×2 or 6×4, 30–35 m^3).
- A three-axle truck with a connected three-axle full trailer (usually 6×2 or 6×4; 35–40 m^3).

From the alternatives illustrated above, the single two-axle truck (4×2 or 4×4) as well as the single three-axle truck (6×4 or 6×6) are commonly used in many tropical countries. Often they are used as "terrain trucks" as they are capable of transporting 5–6-t loads in terrain or along poor cattle-cart roads with deep ruts, and they can be easily turned in narrow places.

A separate bogie with a short beam may be used with the three-axle truck (6×4 or 6×6) to form a truck unit. Before loading, the bogie is placed behind the truck according to the length of the load. Then it is fastened to the longest log to be loaded, and the log is fastened to the truck. After that, the loading is carried out. Before driving empty, the separate bogie has to be lifted onto the deck by the truck's winch or by the truck-mounted loader.

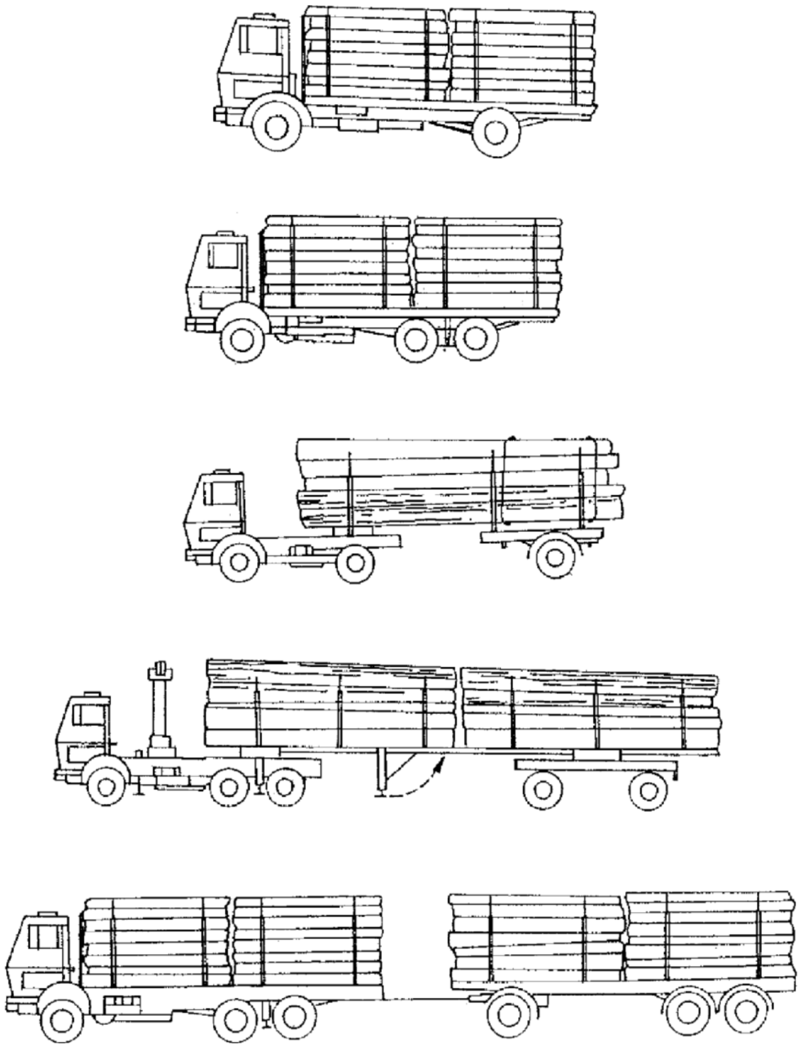

Fig.9.1. Various truck and trailer configurations. (Courtesy Kantola and Harstela 1988)

A special type of semitrailer for long-log transport has a long boom under the timber bunk (Fig. 9.2). The distance of the semitrailer behind the truck tractor is determined by the length of the log load. During log transport the telescopically adjustable boom is hooked to the rear end of the truck-tractor frame. The tractor and semitrailer act as an articulated unit with less off-tracking than a standard truck-tractor with a semitrailer. Before driving empty, the semitrailer is lifted by the truck-mounted loader or other machine onto the

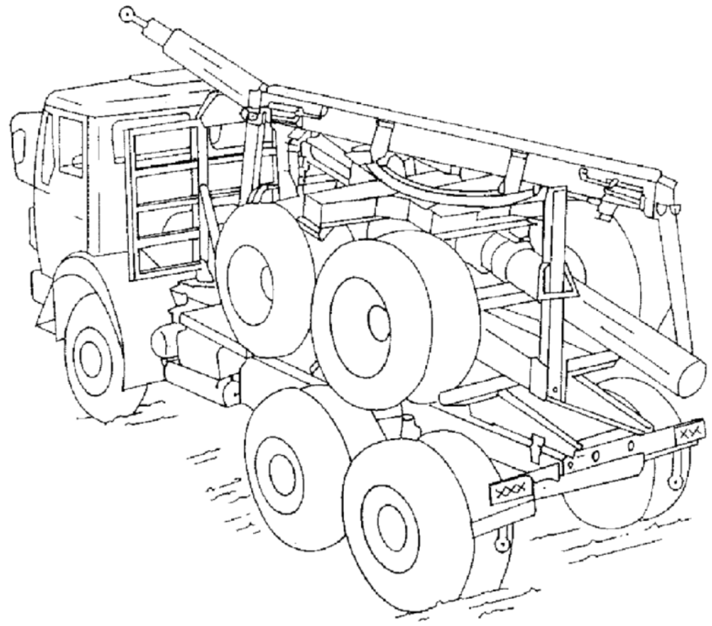

Fig. 9.2. Long-log truck with self-loader and trailer, piggyback. (Courtesy Kantola and Harstela 1988)

tractor. In this way the driving speed of the empty truck can be increased, traction is increased, tire wear is reduced, and the truck is easier to turn at the landing. With some designs, the semitrailer can be loaded onto the truck-tractor, without the use of a loader, by unpinning a hinge connecting the reach to the truck frame and backing the semitrailer against a ramp. Unloading the semitrailer at the landing is done by releasing the brakes on the trailer and letting it back off from the truck-tractor. A three-axle truck (6×2 or 6×4) with a full trailer is used on good roads and for long transport distances. The trailer may have two, or three, or even four axles. It may carry loads of 35–40 m^3. Fully loaded it may weigh up to 50 t, depending upon local road regulations. A full trailer may also be used behind a semitrailer, or several full trailers may be used one behind another, when the roads and traffic regulations allow it. Other alternatives are also available. For instance, a four-axle timber truck with a two-axle semitrailer may be used on very good roads and for long transport distances. It may carry loads of up to 45–50 m^3.

The log bunks are made of steel, and the load is supported by stakes. When using a semitrailer, the bunk of the truck-tractor is equipped with a turning plate (fifth wheel), to allow the load to turn according to the movements of the truck. If a flat bed is used, the bunks are mounted on that.

The stakes are installed at each end of the bunk. Integral stakes which have a safety tipping mechanism can be released while standing opposite the unloading side. The load is bound at least by two binder chains tightened around the log load.

9.1.2 Transport Costs

The yearly costs of truck transport consist of fuel and lubricants, maintenance, repair and service, tires, capital costs, and other fixed costs. In tropical countries, the share of capital costs and other fixed costs may form about half of the total annual costs. Fixed costs can be estimated using Table 2.3. To reduce these expenses, the truck should have enough productive hours per year. The daily costs consist of the capital costs of the truck, which also depend on the yearly amount of transport work, in addition to the daily operating costs. The daily costs per wood unit depend on the load size and the number of round trips per day. The size of the load is limited by the maximum load capacity and the condition of the truck, by the bearing capacity of the roads and bridges, and by other existing restrictions. It also depends on the climatic conditions and the vertical alignment of the road. The time needed for a round trip depends on the loading and unloading time, together with the driving speed and the distance of transport. The costs per load are derived by dividing the daily costs by the number of loads per day. Therefore, the size of the load is significant: larger loads are more economical than smaller ones.

Technical factors may limit the size of the load. A technical restriction may be a weak bridge on the road, or poor weather conditions, such as heavy showers or a rainy season. If a rainy season limits the use of trucks for many months per year, the fixed cost of a heavy truck may be too high. In such a case, smaller trucks are more economical.

Operating costs, including maintenance and repair, may be cheaper for a lighter truck, but calculated per cubic meter and kilometer they may be higher than for heavy trucks. The driving speed of heavy trucks on poor roads is low, consumption of fuel high, and need of repair extensive; therefore, heavy trucks may not be suitable on poor roads.

The road speed of a timber truck is mostly affected by the quality of the road, the number of adverse gradients, the radius of curves, suitability of the truck, and the competence of the driver. The costs of truck transport are affected by these speed factors. For example, when driving on a public road at a speed of 40 km/h, the costs per cubic meter per kilometer may be only half of those when driving on a forest road at a speed of 10–15 km/h. Consequently, the proper construction and maintenance of forest roads is important.

Legislation may set restrictions on the axle weight, width of the truck, length of the load, and thereby on the load size of a truck unit. When more axles are used in a truck unit, larger loads may be allowed. However, the total weight of a loaded vehicle on different kinds of roads and bridges may be restricted.

The transport of fresh wood is more expensive than that of dried wood; however, the transport of recently felled timber may be essential to avoid deterioration. The transport of longwood is usually less expensive than the transport of shortwood. An exception is the transport of longwood of poor form which limits the tonnage that can be loaded on a vehicle. Large variations in the need for repairs are caused by the care of the driver. The productivity of log transport is affected by driver skill. If the driver owns the truck, he is more likely to be careful. Excessive delays in transport result in high interest costs and disturbance in other operations. A skillful driver can influence the service life of his truck and at the same time diminish costs and the danger of accidents.

To organize the operations economically and to maintain the roads accordingly, truck transportation should be planned and coordinated. Poor roads should be used in good weather conditions and better roads at other times. When several trucks are used on the same narrow roads, traffic synchronization may be needed to avoid waiting times at loading sites or passing points. Scheduled speeds must be followed by the drivers. Registration and reporting devices and activities should be arranged.

9.1.3 Variable Tire Inflation

The use of radial tires and reduced tire inflation pressure is one method that can be used to increase the season of operation, improve traction, reduce vehicle operating costs, reduce road maintenance, reduce the depth of required road surfacing, and improve environmental performance of forest roads. At reduced tire pressure the footprint of the radial tire will increase (Fig. 9.3). The longer footprint reduces shear stresses for powered tires as well as for all tires during braking, improving traction and reducing the tendency to washboard. The longer footprint also increases the bearing area of the tire so that vertical stresses are reduced (Fig. 9.4).

The objective is to match tire inflation pressures with specific operating conditions defined by speed, terrain, load, and road surface strength. At lower pressures, impact loads to the road surface are reduced and washboarding and rutting are reduced. With less rutting, surface erosion from roads is reduced. Reports of crushed rock savings of 25% have been reported by reducing tire pressure from 690 to 345 kPa. Under severe road roughness conditions, travel speed can actually increase owing to reduced truck vibrations, and reduced tire pressures have been reported to smooth and flatten existing washboards.

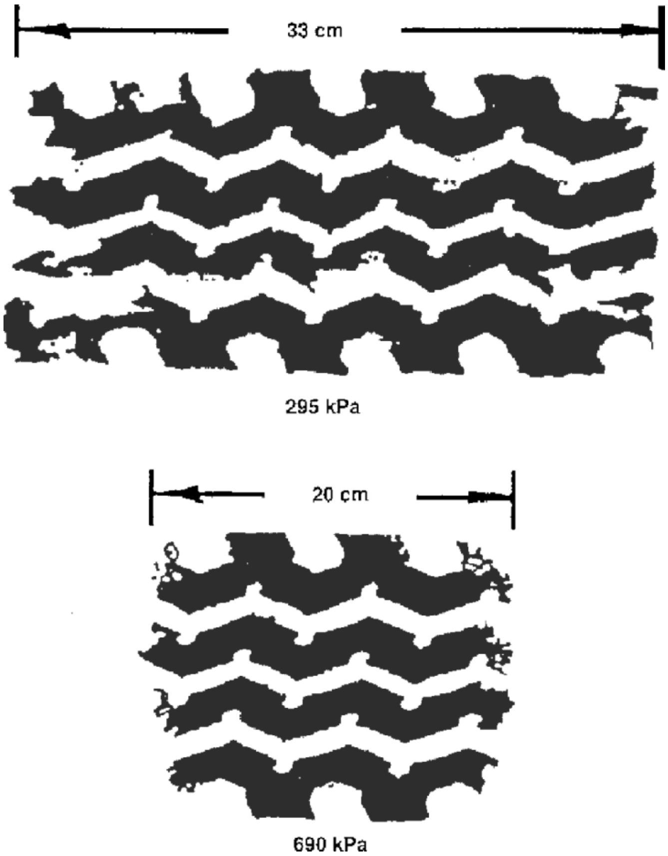

Fig. 9.3. The footprint of a radial tire will change size with different inflation pressures

Many radial-type truck tires can be safely operated at pressures 50% less than on-highway tire pressures if speeds are reduced to 60 km/h or less. Tire pressures can be adjusted manually when trucks enter the forest road system or trucks can be equipped with compressors, airlines, and controls that permit air pressure to be adjusted while vehicles are moving. On-board truck inflation systems can increase truck purchase costs by 10–20%. Costs for adjusting tire inflation, whether manually or automatically, must be balanced against savings in road surfacing costs, road maintenance costs, truck maintenance costs, and driver productivity. For situations where trucks only operate within the forest at speeds of 60 km/h or less, the tire pressures can be permanently reduced without purchase of additional inflation systems or controls. However, the benefits of reduced tire inflation require the use of radial tires as bias ply tires

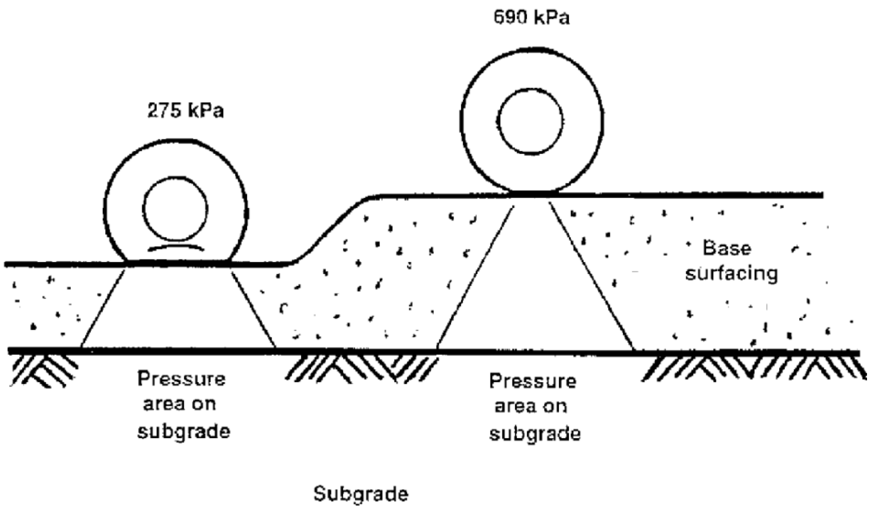

Fig. 9.4. Reduced pressure in a radial tire requires less surfacing to distribute loads to the subgrade

deflect differently under reduced pressure. Reduced tire pressure should be considered not only for log-haul trucks, but also for dump trucks.

9.1.4 Truck Maintenance and Repair

To transport wood safely, efficiently, and economically, the maintenance and repair of the trucks must be arranged. This must be planned and organized according to the scale of the operation and the degree of utilization of the trucks. A supply of spare parts should be obtainable, fuel stations and repair shops should be available, and capable machine mechanics should be trained.

The maintenance program of each truck should be given to the driver. His responsibility is to know when the truck has to be maintained at a fuel station and for which cases a repair shop is needed. He should be capable of carrying out certain maintenance operations and small repairs which do not require special tools.

Trucks require daily service. According to the check list a certain number of critical points must be checked. The level of the engine oil, gear-box oil, water level in the cooler, lights, and air pressure of the tires must be checked before starting out. Checking under the truck may reveal an oil leak or possible breaks in the spring joints. This is usually the best time for refueling too.

At the end of the day, damages and faults must be reported in order to get them repaired before the next shift. The repair service should be arranged so that small running repairs can be made immediately after the day shift of the driver.

Periodic maintenance is done according to the check lists on the basis of the kilometer reading. They also indicate which operations must be done in a repair shop or at a fuel station. The operator's manual specifies the tasks needed at different intervals. They may be lubrication, change of motor oil, motor filter, and hydraulic filter, or air/water removal from the container of the brake system. Cleaning or replacement of certain parts, or other tasks, may be needed after a certain number of kilometers.

Preventive maintenance in a repair shop or fueling station is needed at certain intervals. Critical parts of the truck may be replaced, and in this way the standing time of the truck considerably reduced. Urgent repair is needed when a breakdown has occurred or when the driver has located some sudden fault through an unusual noise during driving. If he is not able to make a temporary repair, he should stop the truck immediately and seek repair personnel.

9.1.5 Driving and Safety

A truck is an expensive forest machine. It must be driven along difficult forest roads with large loads, as well as on public roads in heavy traffic. If the truck is not handled correctly and maintained properly, truck transport may be difficult, expensive, and dangerous.

Drivers must be trained. Drivers should be provided with the knowledge about the function, structure, usage, maintenance, and repair of a truck unit. If road traffic regulations and legislation exist, they should be known. Drivers should also be familiar with the documents needed in road transport.

Through training, truck drivers should learn the skills of loading, driving, maintenance, and repair. They should also be able to follow the basic safety measures in wood transport. They should learn positive attitudes to orders given, and to accept responsibility in their work. During working hours the drivers should be carefully supervised. They need adequate food, rest, and sleep. No alcohol and no passengers should be allowed. On long distances, a half-way checkpoint for control of the vehicle, refueling, and meal breaks should be arranged. When loading, the driver is responsible for the correct distribution of the load. He must also check that the truck is not overloaded. After loading, he has to check that the stakes are well placed, and tools and accessories are secured, to prevent them from falling or bouncing. Before starting out, the driver must check the brakes of the truck and trailer. It is especially

important that the braking power of the trailer is strong enough. If the brakes of the trailer are weak, the trailer may dangerously push the truck-tractor when driving downhill, or the brakes may fade when sudden braking is needed.

The quality of soil affects tire traction. On dry clay, tire traction ceases at a lower speed than on a sand-gravel surface. On wet soil, especially on wet clay, tire traction is readily lost. On soft surfaces the rolling resistance is high. When a vehicle is starting, it needs to overcome the resistance due to inertia, as well as rolling resistance and grade resistance. The inertial resistance may be equivalent to climbing as much as a 10% grade. Therefore, the landing should be placed on soil with good bearing capacity and if possible the loaded vehicle should depart downhill rather than uphill.

Table 9.1 gives an idea of the engine power required for a loaded tractor with a semitrailer weighing 40 t to maintain a constant speed on a gravel or laterite surface climbing different road gradients. Fuel consumption increases rapidly at higher speeds.

A correct driving speed must be applied. One rule is that trucks should descend a hill in the same gear as they would climb it under the same loaded condition. Trucks which must descend long downhill grades should be equipped with engine brakes to prevent overheating of service brakes. The driver must drive defensively and know his stopping distances. Braking too suddenly can cause jackknifing. The driving speed has to be lowered to match the road conditions and special care has to be applied where roads are poor. Table 9.2 gives an idea of the stopping distance as a function of road gradient and speed on a gravel road.

The driver should stop and check his vehicle at the top of long downhill grades and before entering a public road. For steep uphill grades he should be in the correct gear before he starts up the hill. Shifting gear on a steep grade should be avoided. Before entering a public road, the driver should check his load. If the load needs to be tightened, it must be done to secure a safe drive at higher speeds.

Table 9.1. Speed as a function of engine flywheel power and grade for a 40-t truck on a gravel surface

Grade (%)	Speed (km/h)					
	50 kW	100 kW	150 kW	200 kW	250 kW	300 kW
0	20	37	51	62	72	81
+5	6	12	18	23	29	34
+10	3	7	10	14	17	21
+15	2	5	7	10	12	15

Table 9.2. Example of minimum stopping distance on a gravel surface as a function of speed and grade for a truck with service brakes on all wheels

Grade (%)	Stopping distance (m)		
	20 km/h	40 km/h	60 km/h
0	22	54	97
−5	23	59	107
−10	25	65	121
−15	27	75	143

9.1.6 Extended Terrain Transport

9.1.6.1 Agricultural Tractors with Trailers

In some cases the same vehicle can be used both off the road and for longer-distance transport. This method is called extended terrain transport. In planted forests in flat terrain with a dry, even surface and good load-bearing capacity, extended terrain transport can be carried out with an agricultural tractor. The tractor can be started directly in the stump area and continued on the road. In the case of a 10–15-km road transport, a farm tractor with a semitrailer may be used. For longer distances a truck is required. In this way the terrain transport can be extended economically from the stump area to the public road without unloading and reloading at the landing. Sometimes, conditions on the public roads are so poor that a tractor with a semitrailer is a viable alternative for road transport. Agricultural tractor and trailers or semitrailers are generally used for log transport from plantation forests and short-distance transport in tropical forests. Often they are used for short-distance fuel wood transport.

A farm tractor with a strong engine and a suitable semitrailer may also be used in extended terrain transport. A semitrailer with a load capacity of 3–15 t places a part of its load on the rear axle of the tractor, increasing the traction for the tractor. If a semitrailer with driving wheels is available, it increases the transport capability of a farm tractor in the terrain even more. In the case of long-distance road transport, larger tractors are preferable. Full semitrailers cannot be used off the road.

Depending on the vehicle, and the terrain and road conditions, there may be large variations in the productivity of extended terrain transport. To give some idea of the influence of the transport distance, Table 9.3 gives productivity estimates for a large farm tractor with a semitrailer. The size of the load is assumed to be 6 m^3. The volume of annual transport production is estimated

Table 9.3. Estimated productivity of a large farm tractor pulling a semitrailer

Transport distance (km)	Trips per day	Productivity (m^3/day)
1–5	3	18
6–15	2	12
16–25	1	6

by multiplying the daily volume of production by the annual number of effective transport days. The cost per cubic meter (without road and other additional costs) is calculated by dividing the daily costs of the tractor transport by the daily volume of wood transport. When the economy of a tractor and a truck are compared, it may be shown that the daily costs of a farm tractor are 25–30% less than those of a truck. However, the most suitable solution can be found when the load size and number of turns per day for the transport roads in question are known. The load size greatly affects the productivity and costs, and most for longer transport distances; therefore, vehicles with a large load capacity should be preferred.

The influence of terrain is often decisive. Good productivity can be obtained only on dry, flat terrain with an even surface and good load-bearing capacity. Even small gradients may lower productivity; a maximum manageable adverse gradient for a loaded vehicle may be 6–8%. When driving loaded downhill, on a dry surface, a gradient of 10–15%, or a lateral slope of 5–8%, may be allowed. A wet surface may cause a tractor or truck wheel to spin even in flat terrain.

9.1.6.2
Off-Road Trucks

Trucks used in extended terrain transport are called off-road trucks or terrain trucks. They should be capable of moving even on soft ground and be strong enough to carry heavy loads. Off-road trucks are normally all-wheel drive with large-diameter, wide-base, low-pressure tires. In Southeast Asia one popular off-road truck is a converted 6×6 military transport truck. In other cases, trucks designed for off-road construction or mining have been fitted with a fifth wheel, log stakes, and a pole trailer. These trucks can operate on very steep grades, poor running surfaces, and cross swampy ground. Off-road trucks are used between the log landing and a transfer yard along the main road. In some situations, they are used to haul directly from the landing to the mill or riverside. The economics of using off-road trucks should consider differences in road standards and the extra cost of reloading the logs if a transfer yard is

required, and the costs increase in the hauling season. In areas of expensive road construction, where steep grade road locations could avoid large excavation, landslides, and potential erosion, the use of off-road trucks could be a viable alternative to limit environmental impacts. In some cases, landing size can be reduced as the off-road trucks can jackknife in the road to be loaded by a front-end loader. An additional advantage of off-road trucks is the ability to remove logs cut from the road right of way that normally would have to wait until road construction is complete. Often roads where off-road trucks are used cannot be used by on-road vehicles. Tire penetration can be as much as 60 cm. One consideration in the selection of a particular model of off-road truck is the availability of maintenance and parts. Off-road trucks from construction and mining equipment may share many of the same parts as the road construction equipment, so standardizing on a particular manufacturer has maintenance advantages in remote locations.

9.2 Water Transport

In the tropics transportation of round timber by water has always been important. In Latin America, the Amazon, Paraguay, and Parana rivers with their tributaries, are the most important. On the west coast of Africa, from Côte d'Ivoire to the People's Republic of the Congo and the Democratic Republic of the Congo, there are many usable streams and lakes. And, in the Far East, from Bangladesh to Indonesia and Vietnam, timber-producing tropical countries use water transport by driving, rafting, or on barges and ships, and seagoing rafts. Water transport is expected to remain important in such areas, although concerns about effects on water resources may result in some restrictions.

The different methods of transportation by water include extraction from mangrove and tidal forests, from swamps, and from seasonally inundated forests. Water transport is also used in combinations with truck transport for logs from tropical high forests, particularly from remote areas or for export purposes. Manually guided rafts are slow, going down the stream at a speed of 1 or 2 km/h and not traveling at night. Where tides exist, the rafts are held up by the incoming tide. The raft sizes vary within wide limits, from two to three logs of 4–5 m^3 guided by one man in swift water, to 80 or 100 logs of about 300 m^3. These rafts, descending with the stream, are too slow to be an economic success and continue only where tugboats cannot pass. This is usually because of the shallow water which may be deep enough to keep the timber floating but not deep enough for the tugboats, which are not specially designed for the tropics and have a much greater draft than the timber.

For safe and regular rafting of large volumes of timber, tugboats must be used. Traveling day and night, with rafts sizes up to 2,500 m^3, and stopping only at the coast at the time of adverse tide water, tugboats, working in teams of two, can double or triple the speed of manually controlled rafts, and can be guided safely around river bends and between sandbars.

The buoyancy of floating timber depends upon moisture content (with most species having a density of more than 600 kg/m^3 at 15% moisture content). Heavy green timber should not be rafted for long distances without being attached to some type of floater.

All timber to be rafted, floating or not, should be given time to season in order to increase buoyancy and, therefore, the duration of floating. The height above water of the emerging part of the log diameter is only an indication of the wood buoyancy at a given moment, and does not indicate the rate at which the water is being absorbed and how long its floatability will last when it is immersed. Some tropical woods pick up the water faster than others. Some keep their floatability for years and others lose it after a few weeks or months.

Rafts of light timber, riding high on the water, need less towing power and travel faster than those of heavy floating timber or mixed rafts of floaters and sinkers which lie low in the water. Nonfloating timber, called sinkers, can be kept up in a raft by the buoyancy of some lighter wood species, by bamboo bundles, by various palm species, or even by empty gasoline and oil drums.

When timber species with a lot of sinkers are logged, the available light woods may be insufficient to carry all the sinkers. Where the logging site is located within the range of reverse-tide waters, the floaters can be towed upriver and reused, if dried between the raftings. If the timber has to be rafted from locations beyond the reach of the tidal water, to which the floaters cannot be towed back, the floaters can be replaced by empty, sealed gasoline or oil drums brought in shiploads. The drums are placed end to end, in one or two rows, alongside the log and on both sides, and fastened to it with wire. Six to ten logs are bound together to make up the permitted width of the raft. Another system of rafting nonfloatable timber is by the suspension of the logs from outriggers laid across low barges. In forest regions with an excess of floating timber and few sinkers to be transported, the assembling and binding of mixed rafts can be avoided by rolling sinkers from the shore onto the rafts across the floaters and wiring them tightly together so they will not shift.

Sometimes rafts are pushed down the rivers instead of towing them. Logs fastened solidly into rigid rafts of floating timber, or of combined floaters and sinkers, are much easier to guide and to control by pushing than by towing, provided the length and the width of the rafts are properly adapted to the worst river bends and bottleneck passages. By mounting a pushing blade onto the bow, a tugboat can be used independently for both towing or pushing rafts.

The pilot has the raft right under his eyes and all boat maneuvers can be more easily controlled than with towed rafts, which swing freely at the end of a 50-m towline behind the pilot boat. When extracting by floating, two or more logs are usually tied together and, where possible, whole trees are topped and limbed, and then floated using manpower to a storage and rafting center. A motorboat is sometimes used to drag a line of logs attached end to end by chains, or by short cables. For heavy species or in shallow water, the yarding has to be done by cable, or, if the ground can support them, by high-flotation tracked skidders.

9.2.1 Mangrove and Tidal Forests

When located in tidal areas, the tree roots emerge more or less completely at low tide, and access roads have to be opened up by axe and bushknife. Numerous stilt roots, sometimes 1 or 2 m in height, cover the ground and leave no passage between the trees. There are also densely growing air roots, called pneumatophores, just high enough to emerge with their round tops out of the usual high water level, but not strong enough to support man or animal.

Often extraction of wood and wood products is still done by hand, with the use of small paddle boats for transportation. Mechanization of transport by water and by land depends on the type of existing waterways, whether shallow or deep water, whether wide or narrow, the tidal variations of the water level, and the speed of the incoming or outgoing tides. These determine the size and draft of the boats and barges, and also the mechanical equipment they can carry. Such equipment can be mounted permanently on decked barges or scows, and progressively shifted to new logging sites; or it can be rigged up on the shore, on platforms supported by log mats above the high water level.

Trees are cut at low tide, and the timber is pushed along with poles at high tide to deeper water, and then bound into rafts. For timber species which do not float when green, it is often possible to obtain temporary floatability by girdling the trees a few weeks, or a few months, before felling. If labor is scarce, the yarding production can be increased by the use of small motorboats with flat bottoms, for pushing or pulling the logs.

For greater production of nonfloating timber, a motor-driven yarder, mounted on a decked barge, is generally used for yarding and loading. The sheave blocks for the main and haulback cables are fixed to a strong tree near the barge, well-anchored to hold its position during both the rise and the fall of the tide. The sheave block, to return the cable, is fastened to a tall tree in the forest about 250–300 m away. Depending on the yarder capacity and on the timber sizes, logs or whole trees are skidded to the barges and loaded.

9.2.2
Swamps

The small fluctuation in water level in swamps simplifies the choice of working methods and of the required mechanical equipment. Swamps are generally the undrainable low parts of seasonally inundated areas. They do not contain the same wood species as mangrove forests, but contain mostly slow growing durable, heavier hardwoods.

9.2.3
Seasonally Inundated Forests

Working methods and mechanical equipment in seasonally inundated forests depend first on whether the logged timber is a floating species or not, and second on the total volume of the planned output. Floating timbers are cut during the dry season and are hauled out to deep water by animal, manpower, or mechanical transportation. On the riverbank or by lakeshores, the timber is made up into rafts and floated downstream to a shipping port or to a sawmill. In small creeks and rivers the high floodwater may last for only a very short period and, if all timber cannot be put into the water during this time, it has usually to wait on the shore for a whole year for the next flood. Nonfloating timber has to be hauled over land to shipping ports, and on the usual low-quality hauling roads this is best carried out during the dry season unless forest railroads are available.

9.2.4
Driving in Creeks and Rivers

Log driving down creeks and rivers is used for transport when creeks and rivers are too narrow, too fast, or otherwise unfit for the passage of rafts. The logs are floated down the stream to larger rivers or lakes where rafts can be built for further transportation.

Driving large tropical timber in creeks where the water level may rise or fall at the speed of 1 m/h requires good organization in order to profit from the short duration of suitable water levels. The system only works well if the necessary crews are available in time to roll the logs into the water, and if the high water lasts long enough to get all the timber away. To avoid log jams, the logs are often guided by men with long poles.

Depending on the frequency and the intensity of the rains, and on the speed the water is running, sometimes all logs cannot be floated in time or they have

been grounded during the drive and have to wait 6–8 months for the next wet season before there is another chance for driving. Some species may not lose much of their quality during the first season, and some durable timber species may not suffer at all if not exposed too long to the sun. However, if timber cannot be floated during the second wet season and has to wait a whole year more, it can become a complete loss.

9.2.5 Rafting in Rivers and Lakes

Rafts can be bound with vegetable fiber, such as lianas and rattan, or with cable or chains. Rafting long logs in booms is often unsuitable for tropical logs because of the need to negotiate frequent bends in the waterways. A wire, pulled through the rings of spikes which have been driven into the end of each log, is sufficient to hold the logs together and at the same time gives the necessary flexibility for going around river bends.

Longer logs, rafted parallel to the stream direction, are attached to pole crossties, having the same length as the width of the raft. If sections of the same log length are formed, several sections are often tied together to form a long raft. Logs of different length, on the other hand, are attached to the necessary number of riders, and are usually bound into a single long solid raft, with only one layer of logs. If the buoyancy of the floating timber permits it, sawn timber can be transported as a top load. Nonfloatable timber can also form top loads or be bound between floaters.

Along large slow rivers, the necessity for building more rigid rafts for pushing, which would increase transportation costs, has prevented a general change from the towing system.

Many forests in the Far East from India to Indonesia include big pure bamboo reserves, which are harvested every 3–8 years. Small rafts of bamboo are made up of 50 poles, 8–10 m in length, attached together in three layers at the thicker leading end and spreading out fanwise at the rear end.

Several such units may be assembled together, laid one on top of the other, without any binding. The rafts are floated down the river with the current, guided and pushed by a few men equipped with long poles. They advance only a few kilometers per day and sometimes get stranded at low water. They arrive at the mills at irregular intervals and the mills are forced to keep big stocks on shore to ensure continuous production. Bamboo keeps its floatability as long as its cellular structure is not destroyed, and losses during the rafting are limited to bamboo sticks smashed or broken in collisions. Stranded rafts are disengaged from the rest of the floating ones and left to wait for high water.

9.3 Railroads

At one time, railways were a principal method of moving heavy timber from the forest to a river landing or to the sawmill. Temporary narrow-gauge railroads were common in the tropics. Round wooden ties were cut from the adjacent forest. Ties were not treated and were not flattened on the bottom and sometimes not on top and were laid directly on the ground with larger ties dug into the ground. Over swampy ground, longer ties were used to increase support. Rails were spiked directly to the ties. Locomotives from 7–22 t are used to pull low flat cars of 6–10-t capacity.

With the development of modern road construction and maintenance techniques and more powerful and reliable trucks, transport by railway has declined. In areas where well-planned and well-built railroads are already in existence they can often compete with trucks because their construction costs were written off long ago. In other areas, shortage of manpower for railroad maintenance has caused their abandonment.

Railways are most likely to compete with roads when:

- Forests are managed on a sustained-yield basis so that an adequate railway traffic level can be maintained.
- There are swamps to cross where rail construction is less expensive than either road construction across the swamp or long roads around the swamp.
- The transport distance is long enough to justify rehandling of the wood.
- There is the possibility to include cargo from other sources.